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FIELD EVALUATION OF UNDERGROUND STORAGE TANK SYSTEM LEAK DETECTION SENSORS

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EXECUTIVE SUMMARY

State Water Resources Control Board (SWRCB) staff have been conducting a comprehensive evaluation of the effectiveness of underground storage tank (UST) and piping systems, and associated leak detection equipment. The evaluation includes: a field-based research project to determine the frequency and source of releases from single and double-walled UST systems, a field evaluation of automatic tank gauges and automatic line leak detectors, a survey of statistical inventory reconciliation service providers, and a field evaluation of leak detection sensors. This report contains the findings of the field evaluation of leak detection sensors, which are the primary form of leak detection in double-walled UST systems. California's UST population currently consists of roughly 75% double-walled systems, making sensor performance a key element in the detection of leaks from UST systems statewide. The importance of sensors will only increase as older single-walled systems are phased out of service and replaced by double-walled systems.

Leak detection sensors are typically located in tank interstitial spaces, piping sumps, under-dispenser containment, and monitoring wells within excavation liners. They may also be located in groundwater monitoring wells or soil-vapor monitoring wells surrounding the tank system, although no such facilities were included in this field evaluation. California regulations require that all leak detection equipment be functionally tested and certified by an authorized service technician on an annual basis. This report was based largely on data collected from 789 sensors at 124 UST facilities during routine annual testing and certification. Also discussed in this report are 71 responses to an on-line survey on sensor performance, completed by service technicians and inspectors. It is important to note that federal regulations and other state UST programs do not require annual certification of monitoring equipment. One may assume that the sensor performance problems identified in this field evaluation would be significantly more common if California did not require the annual certification of monitoring equipment.

Federal and California regulations require that leak detection equipment be evaluated by an independent third-party testing organization in accordance with recognized protocols. However, these evaluation protocols are designed only to test sensor functionality in a laboratory setting. The objective of this field evaluation was to assess sensor functionality under field conditions. We also set out to determine the adequacy of annual certification testing procedures, and to determine whether sensors in the field perform in a manner consistent with the specifications outlined in their third-party evaluations.

The data collected in this field evaluation demonstrate that sensors can be a reliable form of leak detection only when properly installed, programmed, maintained, and operated. Most problems observed in this field evaluation are due to improper installation and programming of sensors, poor or infrequent maintenance at UST facilities, ignoring alarms, and tampering with monitoring equipment. Poor design, construction, and maintenance of secondary containment systems were also common. Additionally, sensor design and materials played a role in some of the failures observed.

Findings - Effective performance of sensors is also dependent upon the performance of the secondary containment in which they are installed. Therefore, this report's findings are presented in two categories: sensor performance and secondary containment performance.

<u>Sensor Performance</u> - Approximately 12% of sensors had one or more problems at the time of testing. The most common problems observed were sensors raised from the low point of the secondary containment, sensors failing to alarm when tested, and sensors failing to shut down the turbine pump in the event of an alarm (when programmed to do so).

<u>Secondary Containment System Performance</u> - Problems with the performance of secondary containment were more common than problems with sensors. Secondary containment must be kept clean and dry in order for sensors to perform properly; however, water was found in over 10% of secondary containment systems. Liquid product was present in an additional 3.5% of systems. Overall, 31% of the facilities visited in this field evaluation had water or product in one or more areas of the secondary containment system.

Recommendations - Based on the findings of this field evaluation, we propose the following recommendations to improve sensor performance and the effectiveness of leak detection programs based on the use of sensors:

1. Periodic inspection and functional testing of sensors and secondary containment are essential to reliable performance. California currently requires annual certification of monitoring equipment, and triennial integrity testing of all secondary containment. The United States Environmental Protection Agency (U.S. EPA) and states not currently requiring annual certification of monitoring equipment and periodic testing of secondary containment should consider implementing such requirements.
2. Sensor manufacturers should continue to refine sensor design and field testing procedures. Sensors must be designed to reliably operate under the conditions found within the secondary containment of an UST. Field testing procedures should involve functional testing of the sensor, and should accurately determine the ability of the sensor to detect a release.
3. Standard third-party evaluation protocols for sensors should be revised to better reflect operating conditions found in the field. SWRCB UST program staff has been active in the efforts of the National Workgroup on Leak Detection Evaluations to improve the evaluation and review process.
4. Regulatory agencies should call for more thorough training of personnel who install, service, and operate UST leak detection systems. A recent California statute requires training for these individuals, and the SWRCB is currently developing regulations to implement a training standard statewide.
5. Regulatory agencies must have authority to take enforcement action against UST owners and operators who tamper with leak detection equipment. The SWRCB has proposed legislation that would grant regulators administrative enforcement authority, and allow them to "red-tag" facilities that are significantly out of compliance.

INTRODUCTION

Secondary containment for most UST systems has been required in California since January 1, 1984[1]. These "double-walled" systems employ liquid sensors in the interstitial space of UST components, the space between the inner and outer wall of the component. Sensors are designed to detect the presence of liquid in the interstitial space, providing the primary (and often only) form of leak detection in double-walled UST systems. Therefore, their reliable performance is a critical factor in preventing the release of hazardous substances into the environment.

To comply with regulations and provide the most effective leak detection, sensors should be installed at the low point of the secondary containment [i.e., at the bottom of the tank interstice, in turbine sumps (where liquid from leaks in double-walled piping will collect), and in under-dispenser containment (where under-dispenser leaks collect)]. Sensors can also be found in fill sumps, monitoring wells, or anywhere else leaking liquid from the primary containment may collect. Regardless of location, all sensors are designed to perform the same task: to alert the UST operator that liquid is present in the monitored area. This alert is typically accomplished either by activating an audible and visual alarm at a control panel, or by stopping the flow of product through automatic valve closure or pump/dispenser shutdown.

California regulations require that all UST monitoring equipment installed on a UST system (including sensors) be tested and certified annually by a qualified technician[2]. Testing and certification are often witnessed by an inspector from one of the 104 local government agencies throughout the state that implement the UST regulations. The local regulatory agencies implement the statewide UST program, which is overseen by the SWRCB. As the statewide regulatory agency, SWRCB staff often receive comments from technicians and inspectors about the effectiveness of UST monitoring equipment, especially if the equipment is not performing properly. During Spring of 2000, inspectors brought the following specific concerns to our attention:

- The inability of discriminating sensors to detect a layer of hydrocarbon-based product (i.e. gasoline) floating on top of water and to properly distinguish between water and product;
- The inability of polymer-strip hydrocarbon detecting elements to quickly and reliably alarm; and
- The inability of polymer-strip hydrocarbon detecting elements to return to effective operation (recover) after exposure to hydrocarbons.

To determine how pervasive the problems were, SWRCB staff launched a field evaluation of sensors. The first phase (Phase I) of this evaluation was a cooperative effort between SWRCB staff, Veeder-Root representatives, and UST inspectors from the Santa Ana Fire Department, City of Santa Monica, and Oakland Fire Department. Phase I focused exclusively on discriminating sensors manufactured by Veeder-Root. Data were collected from 67 Veeder-Root discriminating sensors at 18 UST facilities in Phase I, between August 2000 and November 2000. Sensors were evaluated for their ability to detect and discriminate between product and

[1] California Health and Safety Code, Chapter 6.7, Section 25291(a)
[2] California Code of Regulations, Title 23, Section 2637(b)

water, using a test method proposed by UST inspectors and further refined by Veeder-Root and SWRCB staff. The information collected provided a clearer picture of how sensors perform in the field. Although a great deal of information was collected in Phase I, the data was limited to Veeder-Root discriminating sensor models only.

With funding from U.S. EPA, we were able to conduct a second phase of field evaluations (Phase II). Phase II was conducted to evaluate the functionality of all types of liquid sensors used to monitor UST systems, including discriminating and non-discriminating sensors of all makes and models. The range of objectives for Phase II was broader than that of Phase I. Field data for Phase II was collected between June 2001 and October 2001. This report includes the findings of both phases, but focuses primarily on Phase II. A summary of Phase I testing results is included in Appendix I.

SCOPE OF WORK

Objectives of the Field Evaluation

The purpose of this field evaluation was to assess the functionality of liquid sensors used to monitor UST systems. The focus was on "real world" effectiveness, with testing performed at operating UST facilities. The field evaluation was designed to:

- evaluate the functionality of sensors;
- check the adequacy of field-testing procedures for sensors (or work with manufacturers to develop field-testing procedures if they were not already available);
- determine whether sensors in the field perform consistently with their third-party evaluations; and
- determine whether the standard U.S. EPA third-party evaluation protocols for sensors are appropriate for each of the sensor types evaluated.

A copy of the workplan for Phase II is included in Appendix II.

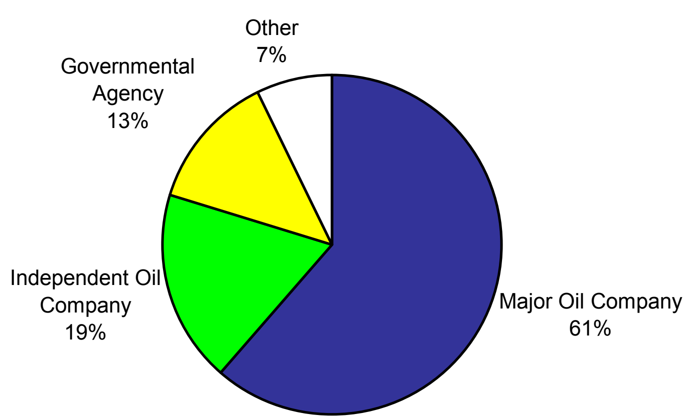
Facility Selection Process

For the first phase of this field evaluation, all facilities were located within the jurisdiction of three agencies assisting in the project; Oakland, Santa Ana, and Santa Monica. All facilities were equipped with Veeder-Root discriminating sensors, and all were owned by major oil companies. In contrast to Phase I, Phase II data were collected from a variety of sensors at a variety of facilities throughout California. An effort was made to include a wide variety of geographic locations, facility ownership types, tank system configurations, sensor manufacturers, sensor applications, and sensor operating mechanisms.

<u>Facility Ownership</u>

Of the 124 facilities in this field evaluation, 76 retail fueling facilities owned by major oil companies and 23 were retail fueling facilities owned by independent marketers. Other types of UST facilities were also included, such as emergency generator fueling facilities, fleet fueling facilities, unmanned card-lock facilities, and government facilities. Figure 1 shows the distribution of facilities in this field evaluation, by ownership.

Figure 1 - Facility Ownership



Geographic Location

Data from facilities within 28 local regulatory jurisdictions throughout the state were included in the field evaluation. Table 1 lists the various regulatory agencies and associated number of facilities evaluated in the field evaluation. A map of California showing the distribution of test facility locations is included in Appendix III.

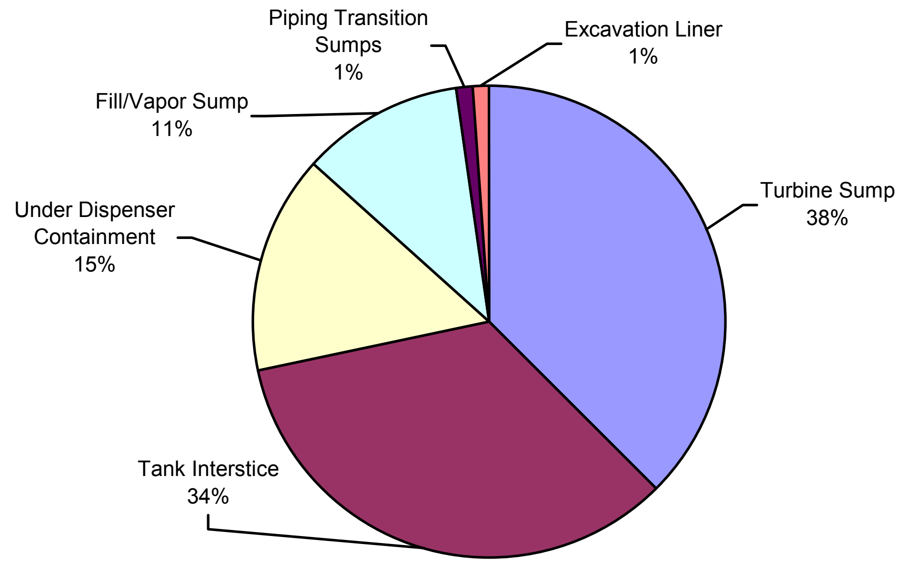
Table 1 - Distribution of Test Facilities, by Regulatory Agency Jurisdictions

Agency	# of Facilities
Anaheim Fire Department	2
Butte County Environmental Health Division	1
Calaveras County Environmental Health Department	1
Orange City Fire Department	1
Colusa County Environmental Health	1
Contra Costa Hazardous Materials Program	3
Fremont Fire Department	2
Fullerton Fire Department	5
Long Beach Fire Department	2
Los Angeles County Department of Public Works	5
Mendocino County Environmental Health Department	1
Mountain View Fire Department	16
Napa County Hazardous Materials Section	3
Newark Fire Department	1
Oakland Fire Department	13
Placer County Department of Environmental Health	3
Sacramento County Environmental Health Department	15
San Bernardino Fire Department	11
San Diego County Department of Environmental Health Services	1
San Francisco Department of Public Health	2
San Leandro Fire Department	1
San Mateo County Environmental Health Department	2
Santa Ana Fire Department	3
Santa Monica Environmental Program Division	7
Solano County Environmental Health Services	16
Torrance Fire Department	2
Yolo County Environmental Health Department	3
Yuba County Emergency Services	1
Total # of Facilities	**124**

Sensor Location

Since all monitoring equipment is functionally tested during the annual certifications at which field data was collected, sensors from various locations within the tank system are included in this field evaluation. Figure 2 shows the distribution of sensors, by location within the tank system. Note that no groundwater monitoring well or soil-vapor monitoring well sensors are included in this field evaluation. While we did not specifically exclude such sensors, they are very rarely used in California.

Figure 2 - Distribution of Sensor Locations



Sensor Manufacturer and Operating Mechanisms

Facilities for Phase II were selected with the intention of including a wide variety of sensor manufacturers and operating mechanisms. Overall, sensor selection represented 8 different operating mechanisms and 15 different manufacturers. Figure 3 shows a distribution of sensors in this field evaluation, by operating mechanism. Figure 4 shows a distribution of sensors in this field evaluation, by manufacturer. In spite of our efforts to include a wide variety, the majority of sensors tested were float switches manufactured by Veeder-Root. Such sensors are by far the most prevalent in California.

Figure 3 - Sensors Tested, by Operating Mechanism

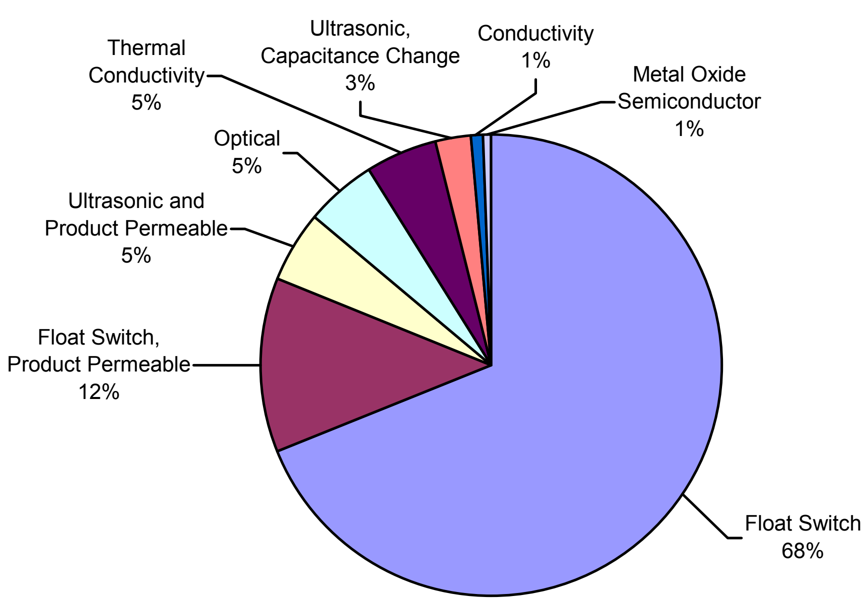
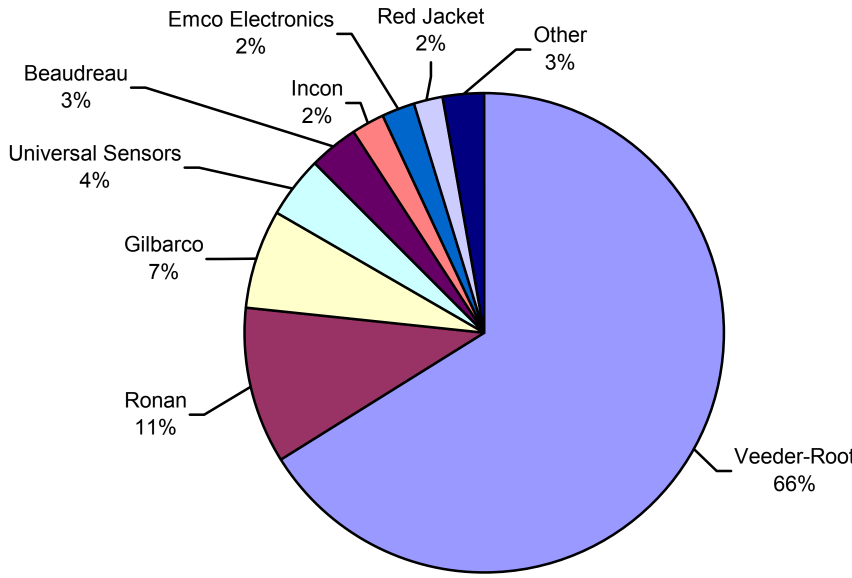


Figure 4 - Sensors Tested, by Manufacturer



Note: Veeder-Root and Gilbarco sensors are produced by the same manufacturer

Scheduling and Coordination

As part of the annual monitoring system certification required for UST systems in California, a qualified technician must functionally test each leak detection component. To minimize the impact on UST facility operations during Phase II data collection, SWRCB staff accompanied service technicians and regulatory agency inspectors during scheduled annual monitoring system certifications. Field data were collected while the technician performed this testing, and the technician's routine test procedures were not interrupted.

Many inspectors and service technicians provided insightful information and data that would not have otherwise been obtained. In total, inspectors were present at 79 of the 106 facilities (75%) evaluated in Phase II. In cases where regulatory agencies do not routinely have inspectors witness annual monitoring systems certifications, SWRCB staff coordinated with the service technicians directly. In total, technicians from 19 service companies performed the sensor testing in this field evaluation.

Data Collection Process

Data for Phase II were collected from 722 sensors in the field between May 2001 and February 2002. Where applicable in data analysis, data from the 67 sensors tested during Phase I were also included. During Phase II, SWRCB staff used a Sensor Data Collection Form to record the make, model, location, condition, response, and recovery times for each sensor tested. Data about facility location, UST system construction type, and personnel present were recorded on the Site Data Collection Form. All field data collected in Phase I was recorded on the Veeder-Root Discriminating Sensor Field Performance Test Form. A copy of each form is included in Appendix IV.

Limitations of Data Collection

Because all Phase II data were collected with the intent of minimum impact on the operation of the UST facility, not all of the desired tests were performed. For example, we suggested that discriminating sensors should be tested both in product and water, and that non-discriminating sensors be tested in water. However, many discriminating sensors were not tested in product, but rather by inverting or submersing the sensor in water. Non-discriminating float switch sensors were often tested by inverting the sensors, rather than by submersing them in water.

When possible, sensor response time was measured from the time the sensor was immersed in liquid (or flipped in the case of some float switch sensors) to the time an alarm was activated at the control panel. In cases where the control panel could not be seen or heard from the sensor location, the time from sensor immersion/flip to the time of pump shutdown occurred was used. In cases where the control panel could not be seen or heard from the sensor location and the monitoring system was not programmed for pump shutdown, field staff would move between the sensor location and the control panel, making their best estimate as to the actual sensor response time.

Several SWRCB staff were involved in field data collection. To reduce subjectivity during data collection, staff met periodically throughout the evaluation to discuss the standards used in recording data. These meetings helped minimize the impact that inconsistent standards may have had on the data collection process. For example, some sensors were found near, but not quite at the lowest point of the secondary containment. One person might consider this sensor to be raised from the lowest point, while another person might consider it close enough to the proper location to record it as being at the lowest point. Through periodic staff meetings, standards were agreed upon and applied uniformly by all staff involved in data collection.

Another factor that may have impacted the results of this field evaluation is the practice of performing maintenance at a facility just prior to the annual monitoring certification. Some inspectors have stated that service technicians often perform these “pre-tests” to assure that the facility will be in regulatory compliance and the monitoring equipment will pass the annual certification. Problems such as failed sensors and water or product in sumps may have been corrected during a “pre-test”, meaning they would not show up during our field evaluation. If “pre-testing” occurred at facilities covered in this field evaluation, failure rates would be artificially lowered. Although SWRCB staff are not aware that any “pre-testing” took place, the possibility cannot be ruled out.

While the findings of this field evaluation are applicable to UST systems throughout the nation, it is important to note that our field data were collected exclusively in California, where annual certification of monitoring equipment is required. This means that a technician had already certified all leak detection equipment at the facilities as operational within the year prior to the data collection. It is reasonable to assume that failure rates may be higher in states where annual certification of monitoring equipment is not required, although such data are not available.

UST Sensor Field Evaluation Survey

To supplement the field data, inspectors and service technicians were polled to provide their personal experiences with sensor performance. Sensor surveys were distributed to regulatory agencies and UST service technicians who work with sensors on a regular basis. With the help of the California Certified Unified Program Agency (CUPA) Forum, an online version of the survey was also made available. A total of 71 surveys were completed, with 63 submitted by inspectors and 8 by service technicians. Copies of the survey and transmittal letter are included in Appendix V.

Data Analysis

To prepare this report, data from both phases of field evaluation were entered into a database. Additional information from sensor manufacturers' installation, testing, and operations manuals have also been used as reference materials. Sensor survey results have been reviewed, and in most instances they validate the field findings. However, the results of the survey are not always consistent with field data. In such cases, it is possible that survey respondents may have negative experiences with a specific sensor model's performance, which could cause them to believe that a particular problem is more widespread than it actually is. It is also possible that we were unable to collect sufficient field data to yield reliable findings in a particular area. In such instances, additional research may be needed to discover why field results differ from survey results.

Although the data collection forms and sensor surveys were designed to adequately record most data, there were many instances where important information could not be captured on a form. In these cases, the "comments" section was used. On the data collection forms, comments describe unique facility layouts, special testing procedures, and additional details on sensor condition and performance. On the sensor survey, the comments include respondents' observations of sensor performance, and suggestions on sensor improvements. Comments from the field data collection can be found in Appendix VI. Comments from the sensor survey can be found in Appendix V.

Failure Rates, by Sensor Make and Model

One objective of this field evaluation was to quantify failure rates for each sensor make, model, and operating principle. We attempted to locate and include facilities with a variety of monitoring equipment. Although 59 sensor models from 15 manufacturers were tested, it was not possible to test a statistically significant number of each model. Therefore, no statistically valid comparison can be made between manufacturers' products. Data on makes and models tested are summarized in Table 2. Sensor performance data by manufacturer are detailed in Table 3.

Failure Rates, by Sensor Operating Mechanisms

Efforts were made to collect enough performance data from sensors so that statistically valid determinations about operating mechanisms could be made. Sufficient data were gathered for float switch, optical, ultrasonic, and product permeable sensors. However, only a handful of capacitance change, thermal conductivity, or metal-oxide semiconductor sensors were included in the field evaluation. Therefore, the limited data may not be a statistically valid to determine the reliability of these latter operating mechanisms. Sensor performance data by operating mechanism is detailed in Table 4.

Table 2 - Number of Sensors Tested and Failures, by Model

Manufacturer	Model	Tested	Failed
Alpha Wire	Unknown	2	
Beaudreau	404	1	
	406	24	3
Emco	Q0003-010	2	
	Q0003-001	5	
	Q0003-002	6	
	Q0003-006	4	
Gilbarco	PA02591144000	24	1
	PA02592000000	8	
	PA02592000010	16	1
	PA0259300000-2	2	
Incon	TS-ILS	1	
	TSP-DIS	1	
	TSP-HIS	2	
	TSP-ULS	15	1
Mallory Controls	Pollulert FD 221GTRA	3	
	Pollulert MD 241RRA	6	1
Mine Safety Appliances	Tankgard 482607	5	2
Owens-Corning Tank	FHRB 810	1	
PermAlert	PSTV	1	
Pneumeractor	LS 600LD	3	
Red Jacket	RE400-111-5	6	
	RE400-203	6	
	Liquid Refraction (Unknown)	1	
	Unknown	1	
Ronan	LS-30	5	
	LS-3	59	4
	LS-7	18	
	Unknown	1	
Universal Sensors	LAVS-1	1	1
	LALS-1	29	2
	LS 03875 STP	3	
Veeder-Root	330212-001	7	
	331102-002	2	
	794380-208	171	3
	794380-209	3	
	794380-300	1	
	794380-301	3	
	794380-302	8	
	794380-320	2	
	794380-322	1	
	794380-341	26	11
	794380-350	39	4
	794380-352	52	1
	794380-408	4	
	794380-500	1	
	794390-205	40	
	794390-352	33	2
	794390-407	20	2
	794390-409	22	2
	794390-420	80	2
	794390-460	4	
	847990-001	6	
Warrick Controls	DLP-1-NC	2	1
Total		**789**	**44**

(Note: Veeder-Root and Gilbarco sensors are produced by the same manufacturer)

Table 3 - Sensors Failing to Alarm, by Manufacturer

Manufacturer	Sensors Tested	Failures	Failure Rate (%
Alpha Wire	2	0	0
Beaudreau	25	3	12
Emco	17	0	0
Gilbarco	54	2	4
Incon	19	1	5
Mallory Controls	9	1	11
Mine Safety Appliances	5	2	40
Owens-Corning Tank	1	0	0
PermAlert	1	0	0
Pneumeractor	3	0	0
Red Jacket	14	0	0
Ronan	83	4	5
Universal Sensors and Devices	33	3	9
Veeder-Root	521	27	5
Warrick Controls	2	1	50
TOTAL	**789**	**44**	**5.6**

Table 4 - Sensors Failing to Alarm, by Operating Mechanism

Operating Mechanism	Sensors Tested	Failures	Failure Rate (%)
Conductivity	9	1	11
Float Switch	539	17	3
Float Switch, Product Permeable	97	3	3
Metal Oxide Semiconductor	1	1	100
Optical	39	3	8
Thermal Conductivity	37	4	11
Ultrasonic and Capacitance Change*	26	11	42
Ultrasonic and Product Permeable	41	4	10
Total	**789**	**44**	**5.6**

* All sensors in this category were Veeder-Root model 794380-341

Failure Rates, by Facility Ownership

The quality of installation and maintenance procedures at a UST facility is expected to affect sensor reliability. An assumption was made that the quality of maintenance and installation would vary depending on the type of facility ownership. Therefore, an attempt was made to gather and compare data from a variety of types of facility ownership. The distribution of sensors by facility ownership is shown in Table 5.

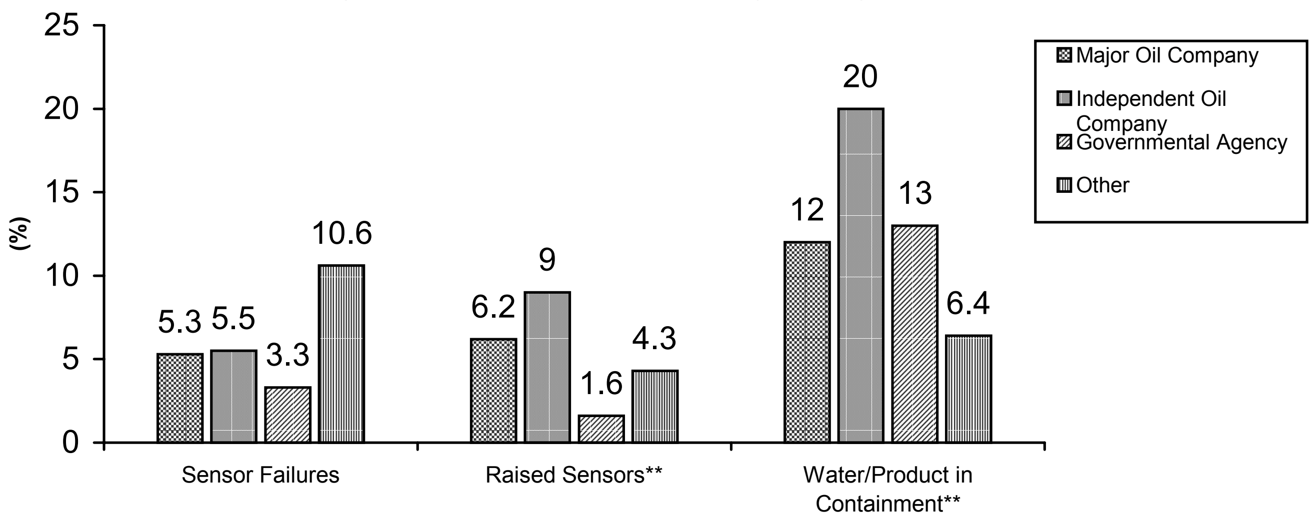
Table 5 - Number of Sensors Tested, by Facility Ownership

Ownership	# of Facilities	# of Sensors
Major Oil Company	76	504
Independent Oil Company	23	177
Governmental Agency	16	61
Other*	9	47
Total	**124**	**789**

* Other includes emergency generator fueling systems, chemical storage tanks, and fleet fueling facilities.

Field data shows that failure rates were similar among major oil and independent owners. Other facility ownership types had a failure rate of roughly twice that of the major and independent oil marketers, although the sample size for "other ownership" was somewhat limited. Independently owned facilities had a noticeably higher rate of raised sensors and water or product in the secondary containment. This may be attributed to less stringent construction standards, or less frequent visual inspection of the secondary containment. Sensor performance data by facility ownership is shown in Figure 5.

Figure 5 - Sensor Performance, by Facility Ownership



**Calculations based on the 722 sensors tested in Phase II, since data on raised sensors and water/product in the containment were not recorded in Phase I.

Performance of Discriminating Sensors Compared to Non-Discriminating Sensors

SWRCB staff have received many comments from inspectors and contractors, stating that discriminating sensors do not perform reliably in the field. Responses to the sensor survey echoed these comments. We targeted as many facilities with discriminating sensors as possible, collecting data on a total of 182 discriminating sensors, including the 67 tested during the Phase I. Of these 182 discriminating sensors, 132 were tested in both water and product. Figures 6a, 6b, and 6c show a comparison between discriminating sensors tested in water only, discriminating sensors tested in both water and product, and non-discriminating sensors. Because the Veeder-Root model 794380-341 discriminating sensors have such high failure rates, and because Veeder-Root has since that time specified that all model 794380-341 sensors should be programmed as non-discriminating, the performance of discriminating sensors excluding the model 794380-341 have also been included for comparison.

Figure 6a - Number of Sensors Tested

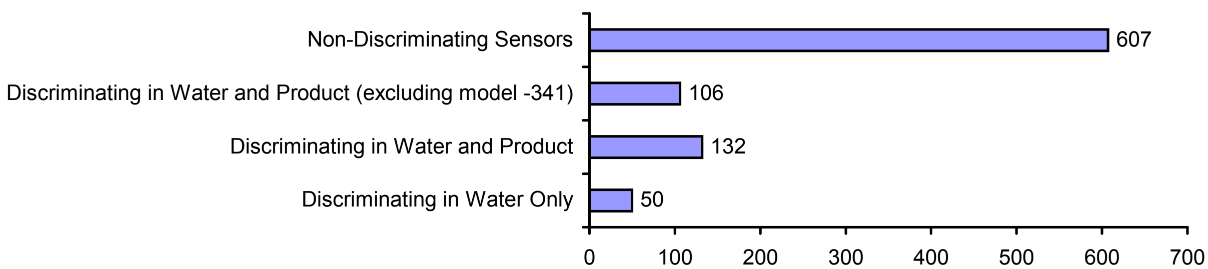


Figure 6b - Perecntage of Sensors Failing to Alarm Properly When Tested

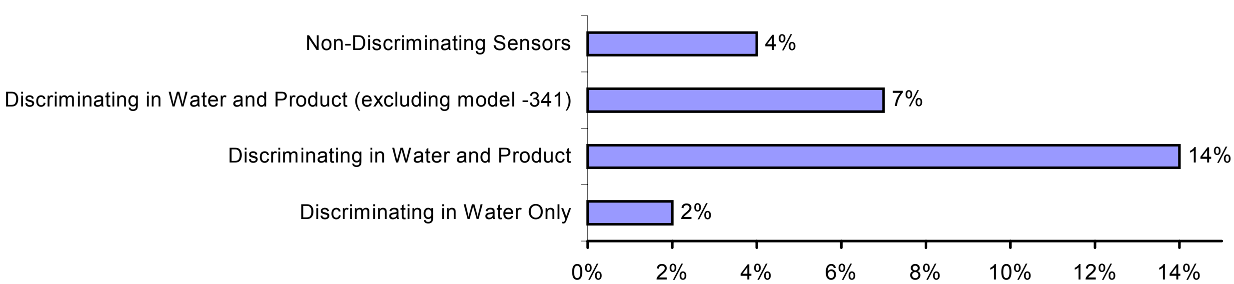
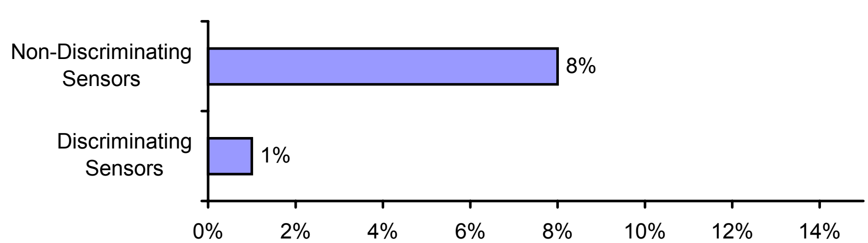


Figure 6c - Percentage of Sensors Not at Low Point



Field data shows that, when excluding the Veeder-Root model 794380-341 sensor, discriminating sensors failed to alarm properly only slightly more frequently than non-discriminating sensors. It is also important to note that discriminating sensors appear to be less likely to be raised from their proper location. In contrast to these findings, 77% of survey respondents stated that discriminating sensors were less reliable than non-discriminating sensors. This may be due to their negative experiences with the model 794380-341 sensor. It may also reflect the fact that our field data has an important limitation. Due to contractors' reluctance to test discriminating sensors in product[3] and the difficulty in locating a wide selection of makes/models, many discriminating sensors were not tested in product. Without test data on more makes and models, and without the ability to test these sensors both in product and water, it is difficult to make a statistically valid statement regarding the relative reliability of discriminating versus non-discriminating sensors. Table 6 lists the failure rates for all discriminating sensors tested in product, sorted by make and model.

Table 6 - Performance Data for Discriminating Sensors, by Make and Model

Make	Model	# of Sensors Tested in Product	# of Failures when Tested in Product	Failure Rate when Tested in Product (%)	# of Sensors Tested in Water Only	# of Failures when Tested in Water Only	Failure Rate when Tested in Water Only (%)	Total # of Sensors Tested	Total # of Failures	Total Failure Rate (%)
Alpha Wire	Unknown	0	-	-	2	0	0	2	0	0
Emco Electronics	Q0003-001	0	-	-	5	0	0	5	0	0
	Q0003-002	0	-	-	6	0	0	6	0	0
Incon	TSP-DIS	0	-	-	1	0	0	1	0	0
Mallory Controls	Pollulert FD 221GTRA	3	0	0	0	-	-	3	0	0
	Pollulert MD 241RRA	6	1	17	0	-	-	6	1	17
Red Jacket	RE400-203	0	-	-	6	0	0	6	0	0
Veeder-Root	794380-320	2	0	0	0	-	-	2	0	0
	794380-322	0	-	-	1	0	0	1	0	0
	794380-341	26	11	42	0	-	-	26	11	42
	794380-350	39	4	10	0	-	-	39	4	10
	794380-352	56	2	4	29	1	3	85	3	4
Total		132	18	13.5	50	1	2	182	19	10
Total Excluding Model 794380-341		106	7	6.5	50	1	2	156	8	5

Determining the Reason for Sensor Failures

It is important to understand what causes failures of sensors in the field. However, the reasons are not always apparent. When possible, SWRCB staff and the technician performing the test attempted to determine the cause of failure. In cases where the cause of failure could not be determined, SWRCB staff followed up with the proper regulatory agency and/or service technician to verify that the failure was repaired and the system was verified functional.

[3] Many contractors state that testing polymer strip discriminating sensors in product is impractical due to excessive response and recovery times. Further, some sensors may not recover after repeated or prolonged exposure to product, thus requiring replacement.

FINDINGS

The findings of this report have been sorted into six general categories: *Sensor Design and Performance*, *Secondary Containment Performance and Compliance Issues, Oversight and Qualifications, Sensor Field-Certification and Testing Procedures, Maintenance and Programming,* and *Discriminating Sensors.* These categories reflect the fact that the condition of secondary containment, the frequency and quality of maintenance and testing, the level of training among operators and service technicians, and the quality of regulatory oversight will all impact the effectiveness of sensors as a leak detection method. The *Sensor Design and Performance* section contains findings applicable to all sensors, while findings pertaining specifically to discriminating sensors have been included as a separate section for easy reference. A section covering *Other facility Observations Not Relating to Sensors* has also been included. However, there is only limited discussion on these observations, since they are beyond the scope of this field evaluation.

A. Sensor Design and Performance

1. **Observation:** Sensors failed to alarm properly for 5.6% of sensors tested (44 out of 789)[4]. A list of sensor failures, by make and model, is included in Appendix VI.
   Likely Cause: Causes varied, but failures are either due to defects in the sensors themselves, or defective/corroded wiring between the sensor and the control panel.
   Consequences: Sensors failing to alarm when tested would likely also fail to alarm in the event of a leak, leading to an increased risk of release to the environment.

2. **Observation:** Sensors can corrode over time. Corrosion interferes with sensor performance in a variety of ways. A common form of corrosion was observed with Veeder-Root 794380-420 float switch sensors installed in the interstitial space of double-walled steel tanks. These sensors have steel housings, which were frequently observed to be cracked. Corrosion can also affect the internal components of a sensor. The field evaluation showed that the moving parts of float switches could become lodged in place due to corrosion. In rare instances, the float had fallen off due to corrosion of the pin that holds the float in place.
   Likely Cause: Materials used in the manufacture of sensors are not always compatible with the stored substances, moisture, and materials found in the secondary containment of UST systems.
   Consequences: Since there is limited space in the interstice of steel tanks, a cracked sensor casing can make it impossible to remove the sensor for testing. Technicians have said that such sensors occasionally have to be abandoned in the tank interstice, with new sensors installed above them. Corrosion of internal sensor components can result in missed detection of product in the secondary containment.

3. **Observation:** Interstitial sensors in double-walled fiberglass tanks can become lodged between the inner and outer tank walls.

[4] This value includes 2 float switch sensors that were in water within the sump prior to testing, but were not in alarm. Although these sensors eventually alarmed when shaken vigorously, they were recorded as failures.

Likely Cause: Sensors are designed to be inserted into a small channel and wrapped around the tank, so that the sensor rests at the low point of the interstice. A pull string is used to position the sensor into the proper position within the tightly confined tank interstice. In some instances, the sensor becomes lodged. Several technicians commented that this might be due to the inner tank settling under the weight of the product stored, effectively pinching the sensor between the inner and outer walls.
Consequences: When a sensor becomes lodged in the interstitial space, it cannot be removed for testing. If sensors cannot be removed for testing, their functionality cannot be verified. Without verifying functionality, a faulty sensor could go undetected, leaving the secondary containment unmonitored. Further, installation of a new sensor is impractical, since the same physical barrier preventing removal of the old sensor will also prevent proper installation of a replacement sensor.

4. **Observation:** Float switches that alarm when tested may not alarm under leak conditions. At two facilities with float switch sensors, a sensor was sitting in sufficient liquid within a sump to activate an alarm, but was not in alarm. Another two facilities had sensors with stuck floats. The sensors went into alarm once the technician removed and shook them vigorously.
   Likely Cause: When inspecting turbine sumps, staff discovered that movement of some floats was hindered by debris, preventing the alarm from being activated until a technician removed and shook the sensor.
   Consequences: Sensors that do not go into alarm because floats are lodged by debris can result in missed detection of product in the secondary containment.

5. **Observation:** Sensors failing to activate alarms when immersed in liquid was observed at several stations.
   Likely Cause: The leading cause appeared to be faulty wiring, which was either installed incorrectly or had degraded over time. Another cause was faulty sensors. At one facility, three of four Beaudreau model 406 sensors installed within the under-dispenser containment failed due to faulty dispenser cut-offs, (similar to a control panel, but designed to cut power to the dispenser when the sensor detects liquid).
   Consequences: Sensors failing to activate alarms when immersed in liquid can result in missed detection of product in the secondary containment.

6. **Observation:** At two facilities in the field evaluation, sensors activated alarms when tested but did not come out of alarm.
   Likely Cause: While further follow-up is required to determine the exact cause, technicians at the facility suspected a short in the wiring between the sensor and the control panel.
   Consequences: Leak detection equipment malfunctioning in this manner needs immediate service. Facilities with pump shutdown will be out of service until the problem is fixed. At facilities without pump shutdown, an operator may choose to ignore the alarm. This leaves the monitored area with no leak detection, and, therefore, poses a risk of release.

B. Secondary Containment Performance and Compliance Issues

1. **Observation:** Approximately 6.5% of sensors tested (46 of 722) were not properly located at the lowest point of the secondary containment[5]. For the purposes of this field evaluation, sensors were recorded as "not at lowest point" if they appeared to have intentionally been raised from their proper location, or if they could not be placed in the proper location due to insufficient length of wiring or a similar reason.
   Likely Cause: In some cases, facility operators may have been raising sensors to avoid having to respond to frequent alarms caused by surface water and/or ground water ingress into the secondary containment. In other cases, the design of the secondary containment may have made it difficult to place the sensor in the proper location, since other components may be in the way. Sumps that have a designated location for mounting the sensor (such as a pipe mounted to the sump wall) reduced the likelihood of raised sensors.
   Consequences: California regulations state that sensors should be able to detect leaks at the earliest possible opportunity[6]. Raised sensors are unable to detect liquid in the secondary containment at the earliest opportunity, placing the facility out of regulatory compliance and increasing the threat of a release to the environment. By raising sensors, facility owners and operators may also be subject to penalties for tampering with monitoring equipment.

2. **Observation:** Water ingress into at least one portion of the secondary containment occurred at 31% of facilities (33 of 106) tested in Phase II. Water ingress was most common in tank-top sumps; 18% (64 of 353) contained water. Water ingress was observed only occasionally in the tank interstice and under-dispenser containment. In 22 of the 75 cases where water was present in the secondary containment, the sensor was raised to prevent alarm. The depth of water in the secondary containment varied from less than one inch to almost two feet.
   Likely Cause: Construction of some secondary containment systems allows surface water ingress. Groundwater may also be entering into improperly constructed secondary containment.
   Consequences: Water in the secondary containment leads to alarms, which may prompt the UST operator to raise or disable the sensors. Water also occupies volume in the secondary containment, reducing its ability to contain product in the event of a release from the primary containment. Further, water may accelerate deterioration of UST components and leak detection equipment since they are not generally designed to be wet for an extended period of time.

3. **Observation:** 11% of facilities (12 of 106) tested in Phase II had product present in at least one portion of the secondary containment. The presence of product was most common in tank-top sumps, where nearly 7% (24 of 353) contained product. Waste oil tanks often contained product in fill sumps. The depth of product varied from less than 1 inch to approximately 18 inches.
   Likely Cause: Releases from primary containment will collect in the secondary containment. In turbine sumps, the apparent cause of most leaks was faulty seals within the pump heads. Diesel fuel was observed most often, likely due to its slow evaporation rate. Careless filling practices are the most likely cause of product in fill sumps.

[5] Calculations based on the 722 sensors tested in Phase II only, since this information was not recorded in Phase I.
[6] California Code of Regulations, Title 23, Section 2630(d)

Consequences: Product in the secondary containment poses a significant fire hazard, as well as an increased risk of release to the environment.

4. **Observation:** Monitoring systems at 2 of the 106 facilities tested in Phase II were in alarm when the service technician arrived to conduct testing. The staff on-site had not taken action in response to these alarms.
   Likely Cause: UST operators may not have been trained in the proper response to alarms. Repeated false alarms may lead operators to ignore them, believing that proper alarm response is not important.
   Consequences: Failure to respond to alarms leads to an increased risk of release to the environment.

5. **Observation:** Some sensors are being used in applications for which they have not been designed. Sensors were used to monitor products for which they are not certified, such as solvents, caustic chemicals, and waste oil. In one case, an interstitial sensor intended for use in a steel tank had been installed in a fiberglass tank.
   Likely Cause: Inadequate training of inspectors and installers plays a likely role in the improper application of sensors. Inspectors and contractors may not know that a sensor designed for use in unleaded fuel may not be effective in waste oil or certain chemicals.
   Consequences: Sensors used with incompatible products may deteriorate more quickly, or be unable to detect a release from the primary containment. A steel tank sensor is not designed to fit within the interstice of a fiberglass tank. Steel tank sensors must operate in a vertical position, but a fiberglass tank interstice is designed to be monitored with a sensor that is installed horizontally. Sensors used in applications for which they have not been designed may not reliably detect a release from the primary containment.

6. **Observation:** Degradation of the tank interstice made it impossible to remove/test sensors in some fiberglass tanks. It is often difficult (and sometimes impossible) to remove sensors from the annular space of fiberglass tanks for inspection/testing.
   Likely Cause: The pull-string used to install and remove sensors from the tank interstice was often missing or broken, making it difficult for technicians to replace the sensors once they were removed. The primary tank tends to settle within the secondary tank over time, effectively pinching the sensor between the walls of the primary and secondary containment.
   Consequences: When sensors cannot be tested, it is impossible to verify that they are functioning properly. For sensors that are removed but cannot be replaced, the tank interstice is not monitored.

C. Oversight and Qualifications

1. **Observation:** Inspectors were present for observation and data collection at 79 of the 106 of facilities evaluated in Phase II (75%). This rate of participation was higher than average due to interest in the field evaluation, and the fact that the inspectors had assisted SWRCB staff in coordinating inspections. The rate of inspector oversight during annual monitoring equipment testing and certification is generally lower.
   Likely Cause: The regulatory agency's resources do not always allow inspectors to oversee monitoring equipment certifications at every facility in their jurisdictions. Furthermore, it may be difficult to coordinate the inspection with the technician conducting the certification.

Consequences: Coordination of annual facility inspection and the monitoring certification allows inspectors to visually inspect sensor locations, and to verify that technicians are conducting the monitoring certification properly. Problems noted by an inspector can often be remedied immediately, using the skills of the service technician already present. These benefits are lost if inspection and monitoring certification are not performed simultaneously.

2. **Observation:** A wide range of knowledge and experience with sensors was observed among technicians and inspectors. Technicians had experience working in the UST field ranging from a few months to over 25 years.
   Likely Cause: The level of knowledge seems directly related to experience. Inspectors and technicians that are new to the UST field are not as knowledgeable about the regulations and equipment as those with many years of experience. Inspector expertise may also depend on the structure of the regulatory agency. Some agencies have inspectors dedicated exclusively to the UST program, while other agencies cross-train inspectors in a variety of programs.
   Consequences: Inspectors and service technicians play a key role in ensuring that a UST facility is properly maintained and regulated. Lack of proper training for the inspector or service technician increases the likelihood of non-compliant or substandard UST systems remaining in operation. Such systems may pose an increased risk of release to the environment.

3. **Observation:** Some technicians performing annual certification of monitoring equipment do not repair or replace faulty sensors at the time of testing. Regulatory agencies may specify that sensors be repaired or replaced within a specified amount of time, generally 30 days.
   Likely Cause: Some technicians who conduct the annual certification of monitoring equipment do not have contracts specifying that they perform repairs. Their responsibility is to test the equipment and report on its functionality. In other cases technicians may have contracts to perform repairs as needed, but do not have the necessary replacement parts or diagnostic equipment.
   Consequences: Facilities may be allowed to operate without functional monitoring equipment for 30 days or longer while repairs are scheduled and completed.

D. Sensor Field-Certification and Testing Procedures

1. **Observation:** Float switch sensors are often tested by flipping them rather than immersing them in liquid. Some sensors that had been immersed in water without activating an alarm were found to activate an alarm when flipped.
   Likely Cause: Flipping or shaking a float switch sensor can free up a float that may be clogged by dirt or debris. Some technicians believe that immersing the sensor in water during testing promotes corrosion, thus reducing the effective life of the sensor.
   Consequences: Manually flipping a float switch sensor is an effective method of activating an alarm condition, and verifying that monitoring system responds accordingly. However, flipping a sensor over does not accurately simulate the conditions a sensor encounters in the event of a leak.

2. **Observation:** Under-dispenser containment (UDC) boxes with mechanical floats and chains (i.e. Bravo Boxes) are not commonly tested. The inspector required functional testing of the float-and-chain UDC leak detection device at only one of the 106 facilities tested in Phase II, and no test results were recorded or included in our database. Occasionally during this field evaluation, inspectors looked to see that the chains were connected. According to the few inspectors who routinely require testing of float-and-chain UDC leak detection devices, the failure rate is high.
   Likely Cause: The common reasons given by service technicians and inspectors for not testing these sensors is that the process takes too long or is too difficult.
   Consequences: Without periodic testing, faulty equipment may go unnoticed. This equipment may not function properly in the event of a leak from the primary containment, leading to an increased risk of release. Additionally, undetected releases from primary containment may accumulate in secondary containment and pose a significant risk of fire, particularly in the UDC.

3. **Observation:** Old equipment is still in use at a number of facilities, even though the manufacturers are out of business or no longer support the product.
   Likely Cause: As long as their old leak detection equipment continues to function and is in compliance with regulatory requirements, there is no incentive for an owner to replace these devices.
   Consequences: Although this equipment may still be functioning, it poses a number of potential problems. Technicians may not be familiar with operation and testing procedures for obsolete systems. If the manufacturer is no longer in business, there is generally no service technician training available. Technicians may also be hesitant to test equipment for which replacement parts are unavailable.

4. **Observation:** Test procedures are inconsistent. Procedures vary from one contractor to the next and from one regulatory agency jurisdiction to the next. For example, some technicians tested float switch sensors by inverting them, while others dipped them in water. Some thermal conductivity sensors were tested in liquid, while other technicians blew on the sensor to activate an alarm.
   Likely Cause: Many manufacturers do not provide detailed step-by-step field testing procedures and training. Some technicians may not have received training from manufacturers on field testing procedures. In addition, some inspectors may not believe that manufacturers' procedures are adequate and may require sensors be tested in a way other than that recommended by the manufacturer.
   Consequences: Without standard testing procedures, the possibility exists that inadequate procedures may be used. In such cases, there is no assurance that the sensors would reliably detect releases from the primary containment.

E. Maintenance and Programming

1. **Observation:** The pump shutdown (PSD) feature is not always functional. Additionally, we observed a wide range of pump shutdown response times. Times ranged from nearly instantaneous to several minutes.

Likely Cause: Technicians in the field attribute PSD failure to sticky relays. Factors affecting shutdown time include control panel model, software version (particularly with the Veeder-Root/Gilbarco panels), and complexity of leak detection equipment at the facility. (For example, the more sensors at a facility, the slower the shutdown).
Consequences: Pump shutdown failure could result in piping sumps or under-dispenser containment overflowing in the event of a catastrophic piping failure.

2. **Observation:** In many instances, a console had not been programmed according to the facility monitoring plan.
Likely Cause: Many monitoring equipment manufacturers provide the user with a variety of set-up and alarm options for their facilities. These options include activating pump shutdown, indicating a warning instead of an alarm, or dialing out to a remote location in the event of an alarm condition. In cases where the console set-up did not match the monitoring plan, it is possible that the console was not programmed correctly at the time of installation. Programming may also have been changed, intentionally or inadvertently, either at the console or remotely via a modem connection.
Consequences: Programming of the monitoring console affects sensor performance and the ability to properly alert an operator in the event of a problem. Improper programming may also place a facility out of regulatory compliance.

F. Discriminating Sensors

1. **Observation:** Although field staff requested that discriminating sensors be tested in water and product, this was only done 56% of the time (65 of 115 discriminating sensors)[7].
Likely Cause: Many technicians and inspectors are hesitant to test discriminating sensors in product due to the long response and recovery times. There is also a concern that the sensors may not recover after being exposed to product, and will have to be replaced.
Consequences: Unless a discriminating sensor is tested in product, the functionality of one of its operating modes is not verified. Since the sensor's full performance is not determined, there is an increased possibility of missed detection.

2. **Observation:** Many of the Veeder-Root 794380-341 sensors (shown in Figure 8) exposed to product indicated a water alarm. This problem was observed in 13 of 26 model 794380-341 sensors in the first phase of testing, and 9 of 17 in the second phase. Overall, the model 794380-341 sensor failed to alarm properly approximately 50% of the time.
Likely Cause: Since this problem is specific to the model 794380-341 sensor, there is likely a design or manufacturing flaw.
Consequences: UST owners and operators generally consider response to water less urgent response than product alarms. Therefore, product in the interstitial space that is falsely identified by the sensor as water may pose an increased risk of release to the environment.

3. **Observation:** Response and recovery times of the polymer strip element when exposed to fuel were sometimes excessive, and not always consistent with third-party claims. Response times in a gasoline/water mixture ranged from 5 to 12 minutes, with an average of

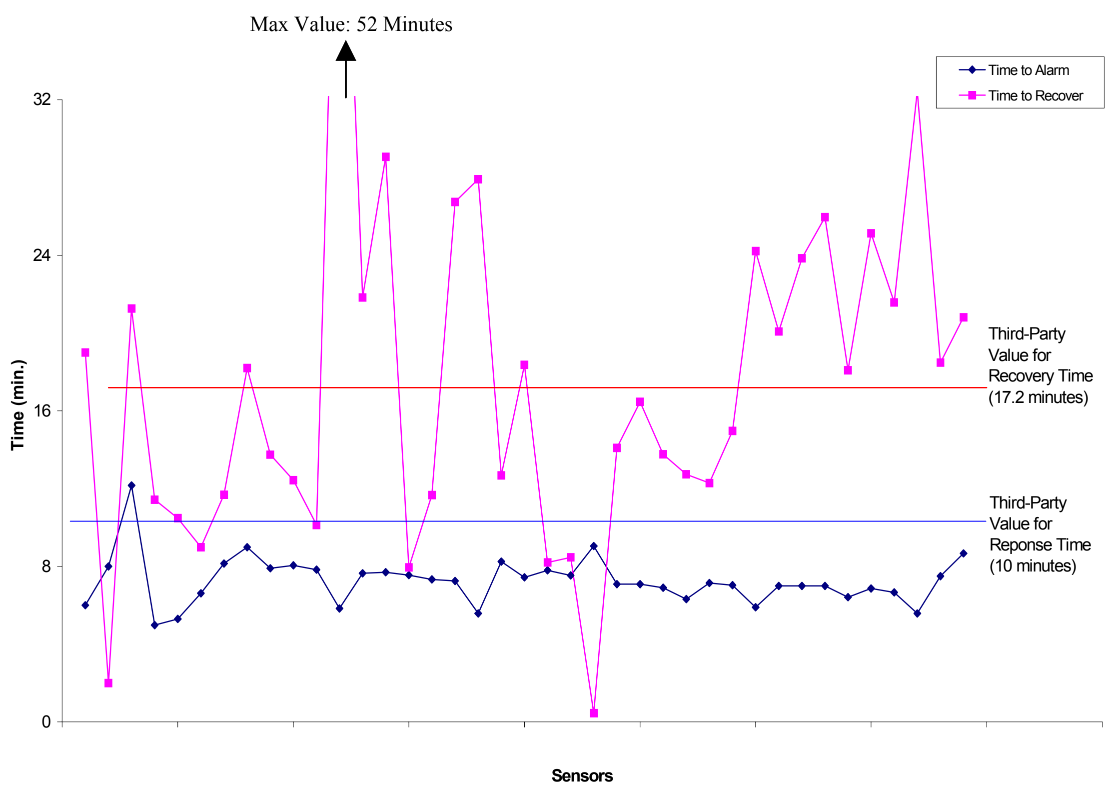
[7] Does not include sensors tested during Phase I, since testing in product was mandated during that phase.

approximately 7 minutes. Recovery times in gasoline ranged from 1 minute to over 50 minutes, with an average of approximately 17 minutes (see Figure 7).[8]

Likely Cause: The fuel alarm is activated only after enough fuel has permeated the polymer strip to raise its electrical resistance to a set value. Typically the resistance in the strip did not begin to change appreciably for several minutes.

Consequences: A primary concern with polymer strip discriminating sensors is the amount of time they take to alarm. In the event of a catastrophic leak from pressurized piping, the slow response time could allow for a large release of fuel into the UDC or containment sump before the alarm sounds. When the liquid level reaches the high-level liquid set point, a high-level water alarm will sound. It could still be many minutes before the polymer strip reacts to the fuel and activates a fuel alarm. This could be a major concern if the system is not configured for turbine shutdown when the high-level water alarm is activated. An additional concern is the wide variation in response times from one sensor to another. With such variation, it is difficult to determine exactly how long a polymer-strip sensor should typically take to alarm once exposed to fuel, to establish field-testing guidelines, or to determine if a sensor is actually non-functional or just slow to respond.

Figure 7 - Response and Recovery Times for Veeder-Root Model 794380-352 Polymer Strip Discrminiating Sensors Tested in Gasoline/Water Mix (Phase I)



[8] A thorough discussion on response and recovery of polymer strip discriminating sensors can be found in the "Summary of Test Results from Phase I Testing," which is included in Appendix I.

4. **Observation:** Current third-party protocols may not be appropriate for polymer-strip sensors. **Likely Cause:** Third-party evaluators have been using a standard liquid point detection protocol to evaluate polymer-strip sensors. These protocols are designed for mechanical or electrical switching devices that do not use chemical reactions like the polymer strips. The protocol does not take into account factors that may affect polymer-strip sensors. The ability to alarm and recover in a variety of environmental conditions is not assessed. The impact on response time and recovery time after repeated fuel exposure of these sensors is not evaluated.
   Consequences: Sensors may fail to detect a product release in the field, not respond quickly under certain conditions, and not recover once exposed to product.

5. **Observation:** Some discriminating sensors may not be able to detect product floating on water.
   Likely Cause: Hydrocarbons typically float on water, and most discriminating sensor designs require the sensor to be in contact with product in order to detect it. Therefore, some discriminating sensors will not detect product release when sufficient water is present. The level of water that will result in a missed detection varies depending on sensor design. Designs can be divided into two general categories: Point Liquid Type and Polymer Strip Type. Each of these categories has distinct capabilities and limitations, as described in Appendix VII.
   Consequences: Sensors may not detect a product release when water is present in the secondary containment, which may pose an increased risk of release to the environment.

G. Other Observations Not Relating to Sensors

The following observations do not directly relate to the effectiveness of sensors as a method of leak detection, but are compliance related items that pose an increased environmental risk. Discussion of these observations is limited because they are beyond the scope of this field evaluation, but follow-up and enforcement action may be appropriate.

1. Line leak detectors (LLDs) have a high failure rate when tested with a 3.0 gallons per hour at 10 pounds per square inch leak rate. All staff collecting data for this field evaluation observed failures, although LLD failure data were not recorded. In general, mechanical LLDs failed more frequently than electronic LLDs. SWRCB staff are currently evaluating the effectiveness of LLDs in the field as part of a separate project.

2. Some UST facilities had recently installed under-dispenser containment (UDC), but did not install monitoring devices as required by California regulations[9]. In one case, a small leak from the dispenser piping had resulted in nearly 18 inches of diesel fuel in the UDC. In this case, it appeared that the presence of UDC prevented a release to the environment. However, the leak had gone undetected for some unknown time period, and would have remained undetected if the annual facility compliance inspection were not being performed that day.

3. The overfill prevention devices had been tampered with at one facility. Long sticks had been inserted and left in the fill pipes, effectively disabling the fill tube positive overfill protection device. Comments from technicians and inspectors indicate that this is not uncommon.

[9] California Code of Regulations, Title 23, Section 2636(f)

RECOMMENDATIONS

The following recommendations are designed to improve the effectiveness of sensors as a leak detection method by addressing specific issues observed during this field evaluation. Just like the "findings" section of this report, recommendations are organized into six categories: *Sensor Design and Performance*, *Secondary Containment Performance and Compliance Issues, Oversight and Qualifications, Sensor Field-Certification and Testing Procedures, Maintenance and Programming,* and *Discriminating Sensors.* The *Sensor Design and Performance* section contains recommendations applicable to all sensors, while issues pertaining specifically to discriminating sensors have been included as a separate section for easy reference. Note that no specific recommendations have been made to address the findings listed under *Other Facility Observations Not Relating to Sensors*, since these are beyond the scope of work for this report.

A. Sensor Design and Performance

- **Improvement in the design and manufacture of sensors is needed.** The results of this field evaluation indicate that the environment in which UST leak detection sensors operate can degrade their performance over time. Manufacturers should design sensor housings, wiring, and functional elements to endure UST system conditions for the anticipated life of the sensor.

- **Float switch sensor design should allow for free movement of the float.** For a float switch sensor to operate effectively, the float must be free to move up and down in response to the presence of liquid in the secondary containment. Manufacturers should produce float switch sensors that are not easily obstructed by dirt and debris, or are in an enclosed housing that keeps debris away from the float mechanism.

- **All sensors should be evaluated under field-representative conditions.** Standard U.S. EPA evaluation protocols should be re-evaluated by a workgroup of inspectors, manufacturers, and third-party evaluators. Modifications to the protocols should be made to assure that the evaluation challenges the sensor's performance under conditions likely to be encountered in the field. Once the new protocol is in place, only sensors that have been evaluated by an independent third party in accordance with the revised protocol should be approved for new installations.

- **Sensors should not be used as the sole method of leak detection for double-walled pressurized piping.** This field evaluation has shown that, for a variety of reasons, sensors may fail to detect a release from the primary containment. Therefore, a line leak detector or other leak detection should be used as a backup. This will reduce the risk of release to the environment in the event of a catastrophic failure of the primary piping.

B. Secondary Containment Performance and Compliance Issues

- **Secondary containment should be designed and constructed to prevent the ingress of surface and ground water.** Preventing water ingress will reduce the frequency of water alarms from sensors in the secondary containment. It will also help reduce the tendency of facility operators to raise their sensors to avoid water alarms, and would reduce the amount of water that has to be removed from the containment and disposed of properly. Finally, any adverse impact that water may have on sensors (such as corrosion or accelerated failure of internal components) would be minimized by keeping water out of the secondary containment.

- **Secondary containment should be tested periodically.** Testing will verify that the containment is capable of holding product in the event of a release. Testing will also identify points where groundwater may enter the containment. Once identified, these points can be repaired in order to prevent groundwater intrusion into the secondary containment.

C. Oversight and Qualifications

- **UST operators should be trained about their role in effective leak prevention.** The most common problem observed in this field evaluation was raised sensors. In many of these cases it is likely that the facility operator raised the sensor in order to disable it, or to take it out of alarm when liquid was in the secondary containment. Tampering with leak detection is a regulatory violation, and individuals caught doing so may be subject to penalties and fines. Raising sensors makes the leak detection system less effective, thus increasing the risk of release of hazardous substances to the environment. Training UST owners and operators on proper alarm response and the consequences of tampering with monitoring equipment will help reduce this problem.

- **Enforcement action should be taken against those who intentionally hinder the effectiveness of leak detection equipment.** This includes tampering with sensors, ignoring alarms, turning off monitoring systems, or failing to take action when product or water is present within secondary containment. Enforcement action may also be appropriate for other violations that increase the risk of release to the environment, such as tampering with overfill prevention equipment.

- **UST inspectors would benefit from additional training on the limitations and proper application of sensors.** Some sensors were installed incorrectly for the specific conditions at a particular UST facility. Facility-specific conditions included the type of product stored and the size or shape of the monitored space. By better understanding how each type of sensor operates, regulators can make more informed decisions about the appropriate application and placement of specific sensors when reviewing and approving monitoring plans.

D. Sensor Field-Certification and Testing Procedures

- **All sensors should be functionally tested at least annually.** This annual testing should include under-dispenser containment boxes with mechanical floats and chains (i.e. Bravo Boxes). Testing procedures should also include verification of alarms and pump shutdown where applicable. Monitoring systems that provide shutdown of the pumping system when sensors are disconnected and/or when the monitoring system loses power should also be functionally tested.

- **Testing should be conducted by a qualified service person.** Service technicians should be knowledgeable about UST monitoring systems, and should be trained the manufacturers of the equipment they are working with. Periodic testing should verify functionality of the sensor, and should be conducted in accordance with the manufacturer's recommended protocols, in a manner consistent with all applicable regulations.

- **A standard field test procedure should be developed for each sensor technology.** The procedures should demonstrate each sensor's ability to reliably detect a leak (for example, float switch sensors should be tested in liquid rather than by flipping). Manufacturers should work with technicians and regulators to develop these testing procedures, and should train service technicians to perform the testing properly. Technicians should be required to conduct testing in accordance with standard procedures once such procedures are in place.

E. Maintenance and Programming

- **Secondary containment should be inspected frequently to verify that it is clean and free of liquid (water and product) and debris.** This field evaluation showed that, due to a variety of factors, sensors were not 100% effective at detecting liquid in secondary containment. Therefore, it is important to perform frequent visual inspection of these areas. We recommend that visual inspections be conducted on at least a monthly basis.

- **Float sensors should be inspected frequently (more than once a year) to verify that they are functional.** Float sensors may not work properly if debris and dirt within the secondary containment interferes with the movement of the float mechanism. In order to have effective monitoring of secondary containment using float sensors, frequent inspections and maintenance is important. This recommendation is particularly significant given the prevalence of float sensors (68% of sensors in this field evaluation).

- **Sensors installed in piping sumps to monitor pressurized piping should be programmed to shut down the pump when product is detected.** Most monitoring systems are capable of this function if they are programmed accordingly. Programming the monitoring system to shut down the pump when a leak is detected in the piping is a simple, inexpensive way to reduce the risk of release of hazardous substances to the environment.

F. Discriminating Sensors

- **Veeder-Root model 794380-341 sensors should not be used as discriminating sensors.** The field testing demonstrated they are unable to discriminate between water and product nearly half of the time. However, they were able to reliably determine the presence of liquid. Therefore, all alarms from the model 794380-341 sensors, whether water or product, should be treated identically. Consoles should be programmed accordingly, and Veeder-Root has issued a statement to this effect. We further recommend that all model 794380-341 sensors that fail the annual monitoring certification be replaced with a different model.

- **Discriminating sensors should be tested in water <u>and</u> product as part of the annual monitoring certification.** Since discriminating sensors are programmed to respond differently in product than in water, and since different alarms may receive different responses from on-site staff, it is important to verify that the water <u>and</u> product detection capabilities of the sensor are functional. If long response and recovery times make such testing impracticable, the use of a different type of sensor should be considered.

- **A new evaluation protocol should be developed to effectively evaluate polymer strip sensors[10] under field-representative conditions that may impact their performance.** The protocol should assess the sensor's ability to respond to hydrocarbons in a variety of environmental conditions, and the impact that repeated/prolonged exposure to product may have on the sensor's ability to alarm and recover from alarm reliably. Since current evaluation protocols do not cover these key performance factors, no new polymer strip sensors should be installed until new evaluation protocols are in place and the sensors have been certified in accordance with those protocols.

- **Water alarms from point liquid discriminating sensors should receive a rapid response.** Since point liquid discriminating sensors can only respond to the liquid directly in contact with the detection element, they are unable to detect a product release floating on an existing pool of water whose height exceeds the level of the detection element. To minimize the risk of missed product detection with these sensors, it is important that water alarms be responded to promptly and owners and operators be trained on the limitations of these type of discriminating sensors. Regulatory agencies should consider the limitations of these sensors when reviewing monitoring plans.

- **When installed in turbine sumps and UDC, polymer strip discriminating sensors with low and high level liquid alarms should activate pump shutdown for both product and high-level liquid alarm.** Once the water level has risen above the high-level float, floating product will not come in contact with the polymer cable or strip. There is essentially no leak detection once water reaches the high-level float, so all sensors of this type which are monitoring pressurized piping should be programmed to shutdown the pump at high liquid level. Proper console configuration and operation of the pump shutdown feature should be verified during the annual monitoring certification.

[10] See Appendix VII for a description of polymer strip and point liquid sensors.

- **Longer response times associated with polymer strip discriminating sensors may make them inappropriate for use in certain applications**. Polymer strip discriminating sensors are much slower to respond to hydrocarbons than other sensor types. Therefore, care must be taken when considering their use. Polymer strip discriminating sensors should not be used as the sole monitoring method for double-walled pressurized piping unless they are programmed to shut down the pump when exposed to water or product.

- **Polymer strip discriminating sensors should not be used in UST systems storing diesel.** Since diesel fuel is not as volatile as unleaded fuel, polymer strips respond much more slowly (response times in diesel fuel may be 12 hours or more.) The lengthy response time of polymer-strip sensors in diesel fuel poses an increased risk of release to the environment.

- **Monitoring plans for facilities with discriminating sensors should include response plans for both water and product alarms.** Leaving water in the secondary containment for an extended time period is unacceptable. The most appropriate solution for dealing with water in the secondary containment is to make the containment systems water tight. California's program of periodic integrity testing of secondary containment systems should help minimize water intrusion problems, by identifying and repairing leaks through which groundwater may enter. Regulatory agencies should review response plans to assure that response times for water and product alarms are appropriate based on facility-specific conditions.

- **Discriminating sensors may be reprogrammed as non-discriminating if needed.** In response to the recommendations of this report, or to comply with local ordinances, UST operators may wish to replace their discriminating sensors with a non-discriminating model. As an alternative to replacement, many discriminating sensors can be reprogrammed to operate as non-discriminating. Reprogramming can be a cost-effective solution for discriminating sensors that may not be providing effective leak detection or satisfying local ordinances. Note that only a representative authorized by the manufacturer should perform this reprogramming.

CONCLUSION

The results of this field evaluation indicate that sensors can be an effective form of leak detection only when properly installed, programmed, and maintained. Improper operation, poor installation and maintenance practices, deficiencies in the construction of secondary containment, and poor design of some sensors was observed during the field evaluation. When including instances of water or product in the secondary containment, raised sensors, ignored alarms, and failure of the pump shutdown feature, 12% of the sensors tested had a problem. The problems identified may well be even more common in states not requiring annual certification of monitoring equipment.

To make sensors a more effective form of leak detection, improvements are needed in the following areas:

Functionality of Sensors

- Manufacturers should consider improving sensor design and materials to make them more durable. Sensors should be designed and manufactured to operate under the conditions present at operating UST facilities.
- Sensors should not be used as the sole form of monitoring for double-walled pressurized piping. Line leak detectors should be required as additional protection, to reduce the risk of release to the environment in the event of a catastrophic release from the primary piping.
- Polymer strip discriminating sensors should not be used to monitor for the presence of less volatile hydrocarbons, such as diesel and waste oil.

Field Testing Procedures

- Periodic functional testing of sensors is critical to their effectiveness. Functional testing should be performed at least on an annual basis. However, more frequent visual inspection and preventative maintenance is recommended for all float switch sensors.
- Manufacturers should develop standard field testing procedures, and technicians should be trained on how to conduct field testing properly. Once test procedures are in place, technicians should be required to follow them. Test procedures should demonstrate a sensor's ability to detect a release (for example: testing in liquid for float switch sensors, and testing in both water and product for discriminating sensors).

Third-Party Evaluation of Sensors

- Current third-party certification test protocols for sensors should be modified to better and more thoroughly evaluate sensors, and subject them to the parameters present at operating UST facilities.

Regulatory and Technical Oversight

- Training is needed for UST owners, operators, installers, service technicians, and inspectors. Training should cover proper application, installation, testing, programming, and operation of sensors, as applicable.

- Enforcement action should be taken against those who tamper with sensors, ignore alarms, turn off monitors, or fail to take action where product or water is present within secondary containment.

Design and Construction of Secondary Containment

- Secondary containment should be designed, installed, and maintained to be water tight. This will help reduce the frequency of raised sensors and water alarms, and help prevent deterioration of the sensors and secondary containment.
- Secondary containment should be tested periodically. Periodic testing will help assure that secondary containment can prevent groundwater ingress and contain product in the event of a leak.